The Chemistry Behind Sparklers

By Anne Marie Helmenstine, Ph.D.
Updated November 30, 2019

Not all fireworks are created equal. For example, there is a difference between a firecracker and a sparkler: The goal of a firecracker is to create a controlled explosion; a sparkler, on the other hand, burns over a long period of time (up to a minute) and produces a brilliant shower of sparks.

Sparkler Chemistry

A sparkler consists of several substances:

An oxidizer

A fuel

Iron, steel, aluminum, or other metal powder

A combustible binder

In addition to these components, colorants, and compounds also may be added to moderate the chemical reaction. Often, charcoal and sulfur are firework fuel, or sparklers may simply use the binder as the fuel. The binder is usually sugar, starch, or shellac. Potassium nitrate or potassium chlorate may be used as oxidizers. Metals are used to create the sparks. Sparkler formulae may be quite simple. For example, a sparkler may consist only of potassium perchlorate, titanium or aluminum, and dextrin.

Now that you've seen the composition of a sparkler, let's consider how these chemicals react with each other.

Oxidizers

Oxidizers produce oxygen to burn the mixture. Oxidizers are usually nitrates, chlorates, or perchlorates. Nitrates are made up of a metal ion and a nitrate ion. Nitrates give up 30% of their

oxygen to yield nitrites and oxygen. The resulting equation for potassium nitrate looks like this:

$2\ KNO_3(solid) \rightarrow 2\ KNO_2(solid) + O_2(gas)$

Chlorates are made up of a metal ion and the chlorate ion. Chlorates give up all of their oxygen, causing a more spectacular reaction. However, this also means they are explosive. An example of potassium chlorate yielding its oxygen would look like this:

$2\ KClO_3(solid) \rightarrow 2\ KCl(solid) + 3\ O_2(gas)$

Perchlorates have more oxygen in them, but are less likely to explode as a result of an impact than are chlorates. Potassium perchlorate yields its oxygen in this reaction:

$KClO_4(solid) \rightarrow KCl(solid) + 2\ O_2(gas)$

Reducing Agents

The reducing agents are the fuel used to burn the oxygen produced by the oxidizers. This combustion produces hot gas. Examples of reducing agents are sulfur and charcoal, which react with the oxygen to form sulfur dioxide (SO_2) and carbon dioxide (CO_2), respectively.

Regulators

Two reducing agents may be combined to accelerate or slow the reaction. Also, metals affect the speed of the reaction. Finer metal powders react more quickly than coarse powders or flakes. Other substances, such as cornmeal, also may be added to regulate the reaction.

Binders

Binders hold the mixture together. For a sparkler, common binders are dextrin (a sugar) dampened by water or a shellac compound dampened by alcohol. The binder can serve as a reducing agent and as a reaction moderator.

How Does a Sparkler Work?

Let's put it all together. A sparkler consists of a chemical mixture that is molded onto a rigid stick or wire. These chemicals often are mixed with water to form a slurry that can be coated on a wire (by dipping) or poured into a tube. Once the mixture dries, you have a sparkler. Aluminum, iron, steel, zinc or magnesium dust or flakes may be used to create the bright, shimmering sparks. The metal flakes heat up until they are incandescent and shine brightly or, at a high enough temperature, actually burn. Sometimes sparklers are called snowballs in reference to the ball of sparks that surrounds the burning part of the sparkler.

A variety of chemicals can be added to create colors. The fuel and oxidizer are proportioned, along with the other chemicals, so that the sparkler burns slowly rather than exploding like a

firecracker. Once one end of the sparkler is ignited, it burns progressively to the other end. In theory, the end of the stick or wire is suitable to support it while burning.

Important Sparkler Reminders

Obviously, sparks cascading off of a burning stick present a fire and burn hazard; less obviously, sparklers contain one or more metals, so they can present a health hazard. Sparklers should not be burned on cakes as candles or otherwise used in a manner that could lead to consumption of the ash. So, use sparklers safely and have fun!